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ABSTRACT

The purpose of this paper is to propose the combined use of distinct symbol sets to conduct multilevel process (MLP) analysis and to discuss the application of the technique through a case study example. In turn, consideration is given to the meaning of process analysis, the existent technology of representation, proposed new developments, and suggestions for future research. Throughout, the contention is argued that MLP analysis is an important technique for theoretical formulation, process codification, communication, and the practice of administration insofar as that includes the functions of planning, scheduling, coordination, and evaluation of organization effort. As contrasted with systems analysis and network analysis, process analysis concentrates on one particular component of a system (process) and is concerned with only the first two of four steps of network analysis--system identification, system representation, system validation, and system experimentation. In the course of the discussion, analysis and MLP are differentiated and a variety of examples are examined as a means of achieving common ground for interpretation and estimates of current practice in process modeling. (Author/IRT)

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Multi-Level Process Analysis:
An Alternative Technique For Modeling and Systems Simulation

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Multi-level Process Analysis: An Alternative Technique For Modeling And System Simulation

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The initial premise of this paper is that the current developmental trend in administration reflects increasing emphasis on a theory oriented, empirically validated knowledge base and the growing importance and use of systematic, scientific methods in management. Among the latter, a body of qualitative and quantitative techniques of analysis often described as systems analysis are of special interest. In essence, both theoretical and technological developments are rapidly evolving, gaining in acceptance, use, and noted utility and will have a significant impact on the would-be researcher, practitioner, or teacher.

The purpose of this paper is to propose the combined use of distinct symbol sets to conduct multi-level process analysis and to discuss the application of the technique through a case study example. In turn, consideration is given to the meaning of process analysis, the existent technology of representation, proposed new developments, and suggestions for future research. Throughout, the contention is argued that multi-level process analysis is an important technique for: theoretical formulation, process codification, communication, and the practice of administration insofar as that includes the functions of planning, scheduling, coordination, and evaluation of organizational effort.

Process Analysis

The term "analysis" is employed in the usual sense of decomposition of an entity into fundamental elements for the purpose of discerning what elements and what interrelationships exist among elements. Typically, systems analysis incorporates the same meaning except that the focal point is specifically systems. Therefore, process analysis exists as an intermediate term which is less inclusive and which suggests that the analysis is concentrated on a particular component of the system, in this case, process.

Another term in common use and one which causes some confusion, is that of network analysis (see for example Handy and Hussain, 1969 or Whitehouse, 1973). The term is most often employed to describe ex post facto analysis. That is, the analysis that occurs after a network has been established. An examination of the references cited confirms the observation. Only limited attention is given by the authors to the creation of the network and greatest attention is devoted to analytic procedures thereafter. Further, much of the work is devoted to process networks that are to be implemented either as a result of planning or as a result of the development and redesign of organizational parts.

In contrast, process analysis focuses on the delineation of a process either as it presently operates or as it is conceived to be in the future. The purpose may be to examine functional operation, to better understand the elements and interrelationships, or to derive a model of the entity as a preliminary to simulated experimentation. In this particular instance, process analysis is an integral part of planning and/or policy research.

The conduct of systems analytic studies typically includes four steps:

1. System identification (analysis)
2. System representation (modeling)
3. System validation (assessment)
4. System experimentation (simulation)

Process analysis, as discussed in this paper, addresses the first two steps specifically and leaves open the option as to whether or not the latter two steps are pursued. As will be seen, the study to be discussed includes all four stages.

Other authors (see for example Churchman, 1968; Kaufman, 1972; Morris, 1967; and Handy and Hussain, 1969) recommend a step-wise, analytic procedure that closely resembles variations on the "scientific method" or problem-solving approach. Given that the expressed intent of this paper focuses upon identification and

representation, the purpose can be more succinctly described as arguing for more systematic and combined use of the variety of symbol sets available. It will be clear that such expanded usage enhances understanding, description, and theoretical formulation. To this extent, the approach has considerable theoretical and practical utility.

The Technology of Analysis and Representation

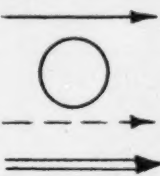
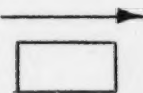
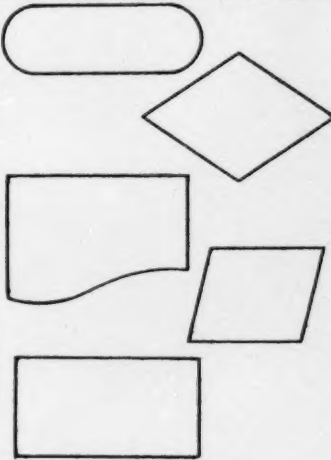
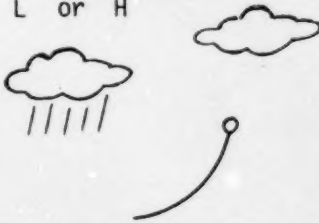
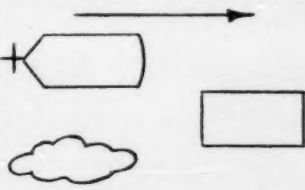
The roots of graphic representation derive from the long established fields of engineering and architecture. There appears to be little practical value in speculating on when such practices may have originated; it is sufficient to state that in these fields such methods have reached a point of high standardization and sophistication.

At some point in the decade of 1940-1950, a new technology (flowcharting) was initiated followed closely by the development of PERT/CPM networks employing yet a different symbol set. The first was in response to the development of computing and the second occurred as a result of a need to coordinate, schedule, and monitor large scale development projects. By comparison, engineering and architectural representations primarily address structure and to a much lesser extent process, while the latter two technologies (flowcharting and PERT) focus almost exclusively on process.

In the more recent past (1965 to present), variety in both symbol sets and usage reflects an undisciplined growth of a technology that is found to be of increasing utility by an array of skilled and unskilled users. A specific objective of this paper is to call attention to the evolving technology and to highlight the need for disciplined use and systematic application.

Table 1 provides a comparison of six distinct graphic methods including (in all but one instance) examples of the special symbols that are typically employed. The exception is engineering drafting where the size of the standardized symbol set now exceeds the magnitude of most dictionaries. The

Table 1
A Comparison Of Commonly Used
Symbol Sets In Process Representation

Graphic Method	Representative Symbol Set	Symbol Interpretation or Explanations for Variable Represented
1. PERT (4 variable set)		Resource consuming activities, flow direction, dependence Events, moments in time Logical dependence w/o resource consumption Critical path; dependence w/ resource consumption
2. Block or systems diagraming (2 variable set)		Flow direction, logical depen- dence Processes; social, technical and combined
3. Engineering drafting (Finite, large variable set)	Too large a set to select	A highly standardized and codified discipline differing modestly from one field to another
4. Flowcharting* (15 or less in the variable set) *ANSI adapted and approved		Terminal interrupt; stop or start logical flow Decision point Hard copy materials (reports, etc.), documents Input/output Any processing function
5. Meteorology (10 or less in the variable set)	L or H 	High or Low areas Cloud Cover Thunderstorm Frontal systems
6. Flow modeling** (10 or less in the variable set) **See Pugh (1970), Forrester (1969), or Garet (1974).		Directed line; indicative of flows Represents a rate value Current status of a state variable Cloud, represents a flow to or from an external source

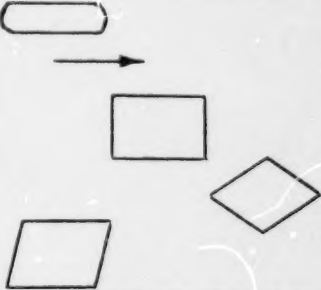
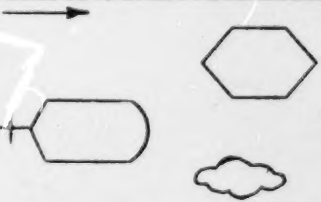
flowcharting symbols that are presented are selected from a set which totals fifteen or fewer. However, those presented tend to be the symbols most often used in the analysis and representation of non-computer process.

From the Table it is apparent that certain commonalities are beginning to emerge and also that a number of redundancies exist. For example, the use of directed lines (→) to represent "flows", activities, logical dependence, or procedural direction appears to be consistent and common to four of the six methods presented. Likewise, the process symbol (□) is common to three of the six methods but the assigned meanings are not consistent since flow modeling (method #6) interprets the symbol differently. However, when both symbols are compared, a further problem becomes apparent. That is, to what extent is the "activity" (→) of the PERT method and the "process" (□) of flowcharting addressing the same act? Obviously, there is some overlap. It would seem that even at this early stage a concern for standardization of the evolving technology would be of value. Further, it may be appropriate to pose the question - what other symbols are in use and might be added to the set? Already, flowcharting methods have standardized that symbol set through the American National Standards Institute (ANSI).

A prominent result which emerges from Table 1 is that the variety of symbol sets or methods depicts a number of important process variables. Is it reasonable to expect that processes have a limited number of elements? That is, will it ultimately be found that a finite set of elements describes all possible processes? Such might be considered a limited element hypothesis. The converse, of course, would be that the elements of a process that are observed are a function of the level under examination; and, that each new level will reveal a new array of building blocks that constitute process. This could be termed the variant element hypothesis which is partially supported by the findings to be presented. The former view would argue for a finite set of symbol representations while the

latter would exhibit greater support for subsets of symbols to represent varying levels of analysis. The latter is a further premise of this paper and hence the nature of Table 2.

Table 2
A Combined Symbol Set With Distinct Subsets

Graphic Method	Symbol	Assigned Meaning
Program evaluation and review (Macro-Level) Subset 1		Activity consuming resources Logical dependence w/o resource cons. Critical path An event
Process analysis (Micro-Level) Subset 2		Stop or start Logical dependence and/or Directionality Process or activity Decision point Input or output
Flow modeling (Micro-Level) Subset 3		Directed flows A level, current status of a state variable A rate variable An external source or sink

In the figures which follow, an effort has been made to present examples of process networks which depict a number of the graphic methods identified in Table 1.

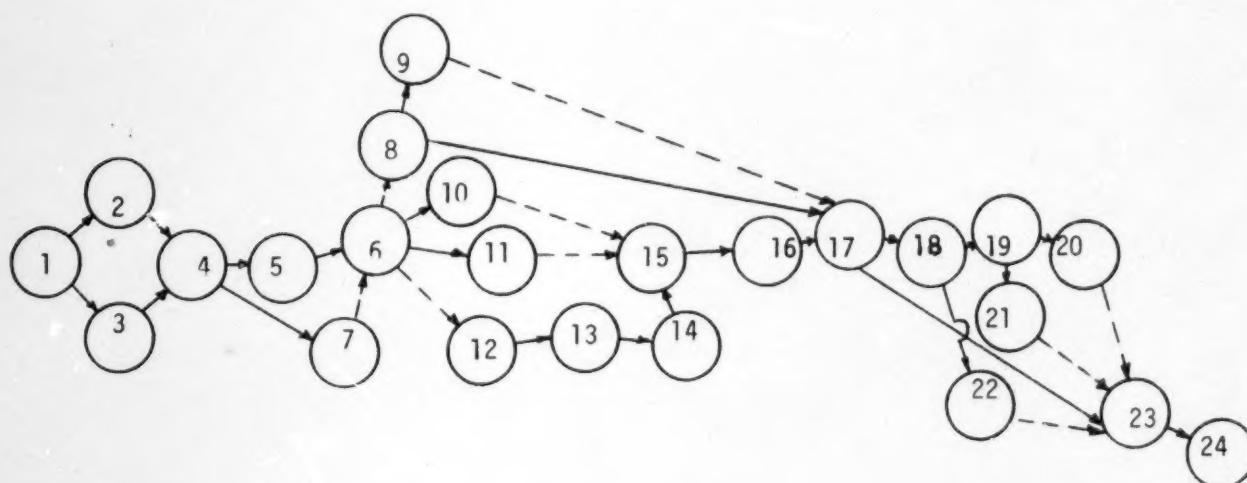
Figure 1 is an example of a PERT network devised by Cochran (1969) to portray elements of a research process. The elements or variables of interest are:

1. Events - moments in time generally representing the conclusion of activities
2. Activities - processes or tasks that conserve resources
3. Logical dependence
4. Initial and terminal points in the sequence.

The relationships among the variables depicted in the network are:

1. Sequential relationships - as in $4 \rightarrow 5 \rightarrow 6$
2. Parallel relationships - as in $1 \rightarrow 2 \rightarrow 4$ and $1 \rightarrow 3 \rightarrow 4$
3. Precedence relations

In all, the network depicts four elements or variables and three relationships among the variables.



Event Identification

- | | |
|---|---------------------------------|
| 1. Project Start | 13. Start Treatment Assignment |
| 2. Complete Theoretical Framework | 14. Start Pre-measures |
| 3. Complete Literature Review | 15. Start Treatment Application |
| 4. Start Objectives | 16. Start Post-measures |
| 5. Start Hypotheses | 17. Start Data Summary |
| 6. Complete Hypotheses | 18. Complete Data Summary |
| 7. Complete Generalization Considerations | 19. Complete Interpretation |
| 8. Start Method Analysis | 20. Complete Conclusions |
| 9. Complete Decision Error | 21. Complete Tables |
| 10. Complete Working Guide | 22. Complete Graphs |
| 11. Complete Treatment Definition | 23. Complete Narrative |
| 12. Start Sample Selection | 24. Complete Bibliography |

Figure 1. Sample PERT Network

In Figure 2, Miles (1975) presents a process model which employs a two-variable, process analysis approach which is labelled block representation. The method is the least abstract of those currently known and has gained in popularity and usage. Two symbols are used: the directed line ($\longrightarrow$) to convey directional flow and the rectangle ($\square$) to denote a sub-process or activity. Given a two-variable (hence, two element) analysis, several relations among elements can similarly be depicted: these include precedence or sequential order, parallel activities, and feedback or iterative relations.

As can be seen, much of the logic of the process is evident; however, there are noted problems. The blocks labelled A, B, and C leave much to be desired in terms of how each of these sub-processes impact upon other activities. Further, it is not immediately clear how one should enter or "begin" the process and once the network is entered it appears there are no logical exits. Hence, one would likely conclude that such a process, once begun, is continuous. The title, however, suggests that such is not the case. That is, presumably the design of learning environments has some logical end.

In a more positive vein, the process model does provide the opportunity to depict feedback paths (iterative relations) and Miles has taken advantage of such potential. PERT is notable among the methods discussed for not providing such capability to the analyst. Hence, if such relations are a priority interest, PERT methods will not be a viable alternative unless specially adapted. By way of a similar comparison, block representation appears to be a one-step advance over previous methods which simply listed process steps in a numerical order.

Figure 3 was taken from the Education Daily (1976) and no other reference was made to the originator. The process model represents a mixed approach between block representation, flowcharting, and PERT methods. That is, the inclusion of a decision variable ($\diamond$) employs a symbol frequently associated with flowcharting, while the straightforward sequential order is similar to PERT methods. Furthermore,

DESIGNING LEARNING ENVIRONMENTS:
a process outline

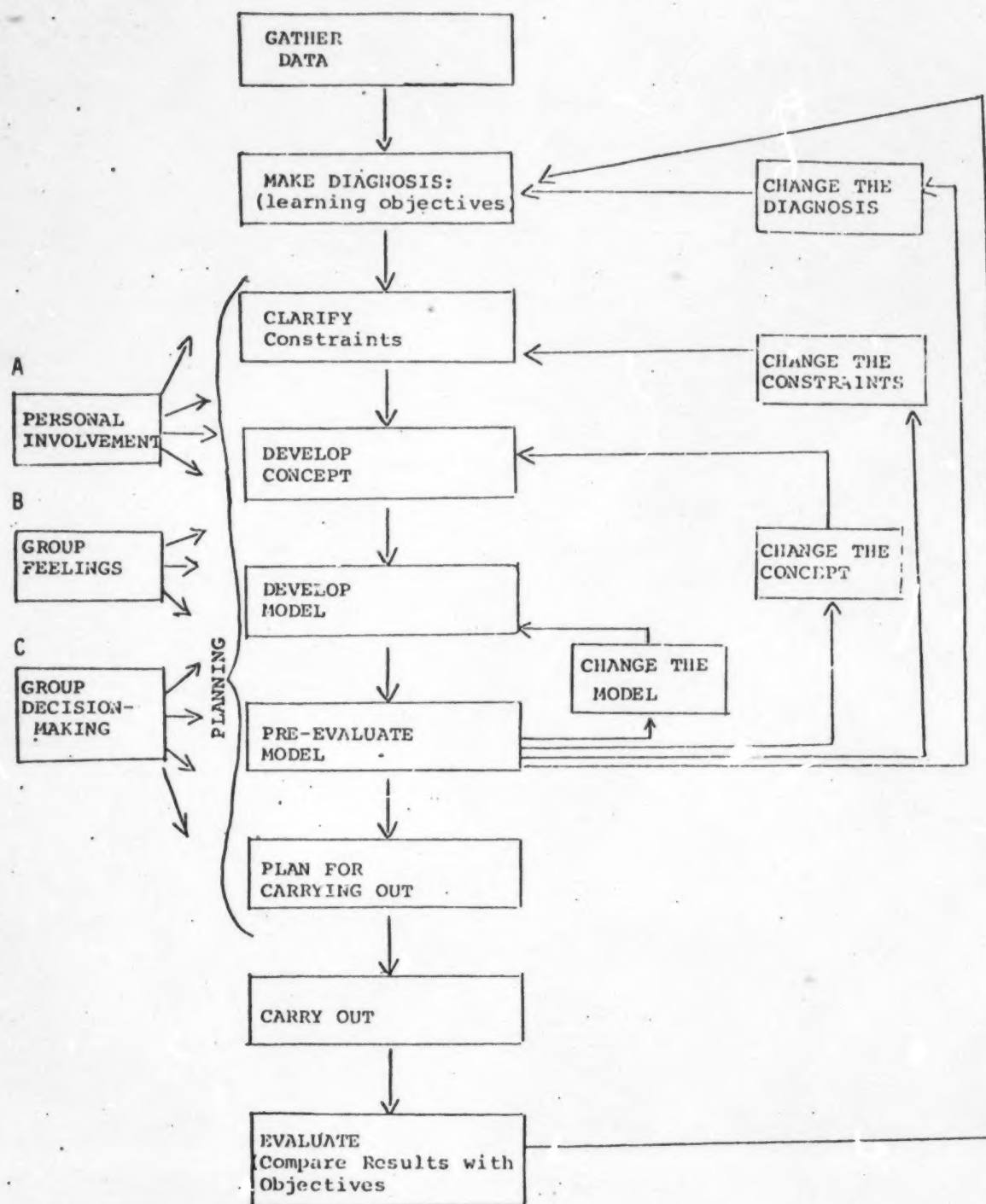
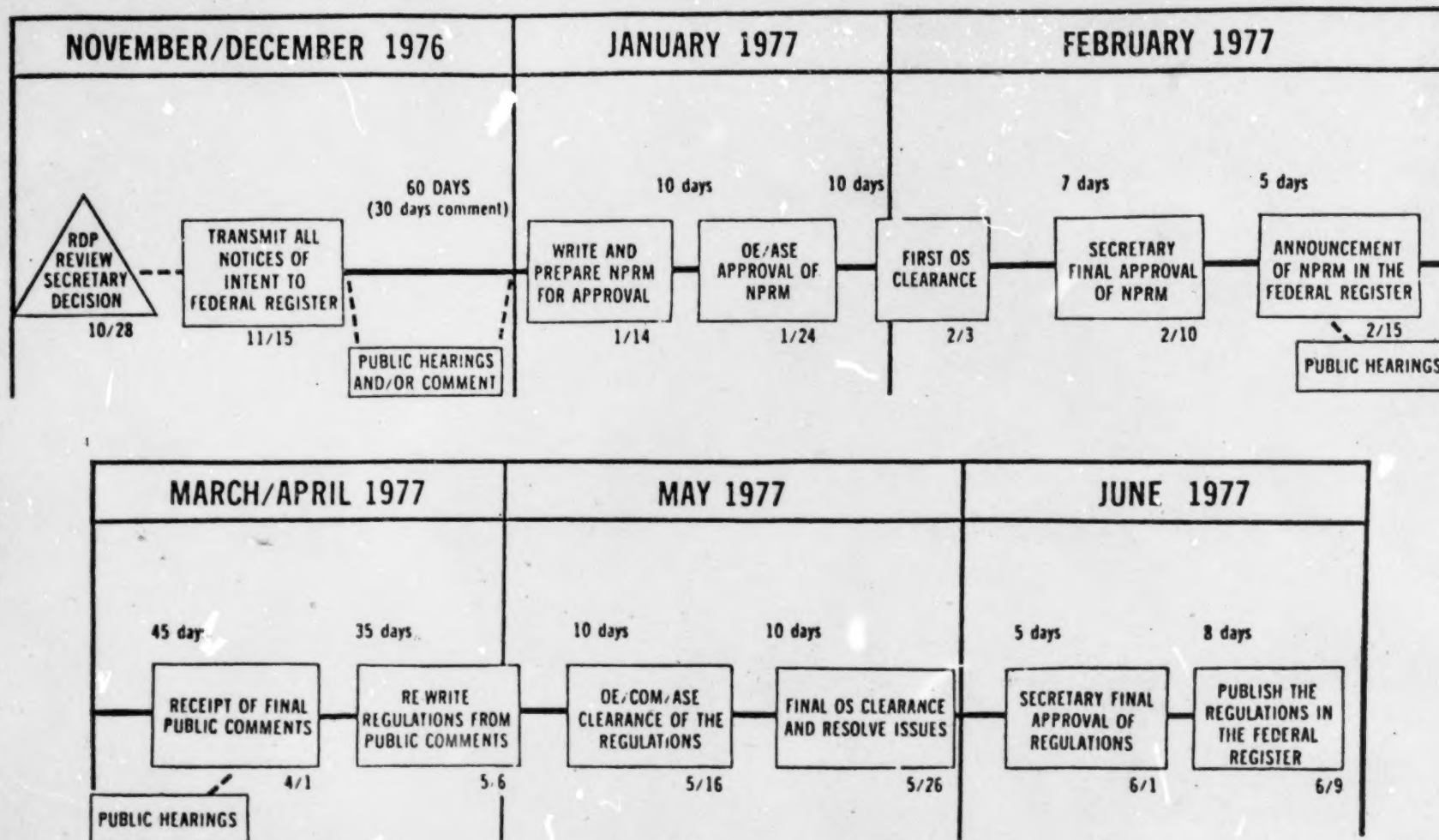


Figure 2. Sample Block Representation

PROTOTYPE SCHEDULE FOR REGULATIONS DEVELOPMENT

Public Law 94-482

Figure 3. Extended Block Representation



the entire process is temporally anchored which introduces, for the first time, a temporal relation.

Overall, this ideal-type model reflects a use of the technology that takes advantage of all symbols, hence all variables of interest, and focuses upon a single level of analysis. The logic of the network is clear and; to the extent that multiple participants were to be involved, it is expected that such individuals would be able to decipher their respective contributions. Thus, this particular network makes use of the variable set of Table 2 in a singular manner which is in direct contrast to the example that will be presented. This, it is felt, is as it should be. That is, the retention of flexibility has decided utility.

Figure 4 is a process model which depicts ideal steps in a planning process. There is increasing contemporary interest in this particular process and this network was produced as an integral part of a long-range planning study conducted by the author (Holloway, 1975). The model is not unlike many that have been more recently proposed (Brejve and Johnston, 1973; Conrad, *et. al.*, 1973) and is an example of a pure use of flowchart symbols.

The analysis reveals three elements of the system: exit/entry points, sub-processes, and decision points. Additionally, three relations among elements are depicted (precedence or sequence, parallel, and iterative relations). The network is not temporally anchored though for any specific effort this might well be incorporated. The logic of the network is consistent and, given that participants understand respective tasks, it is reasonable to expect such a model would contribute substantially to overall coordination. Furthermore, from the standpoint of assessment, the network makes possible contingency analysis and discrepancy analysis at either the ideal or real level and contributes substantially to the work of formative and summative evaluation of the overall effort.

In summary, there are an unlimited number of examples of the use of highly specific process analyses in many areas of the real world. These would include

The Cyclic Nature of Planning

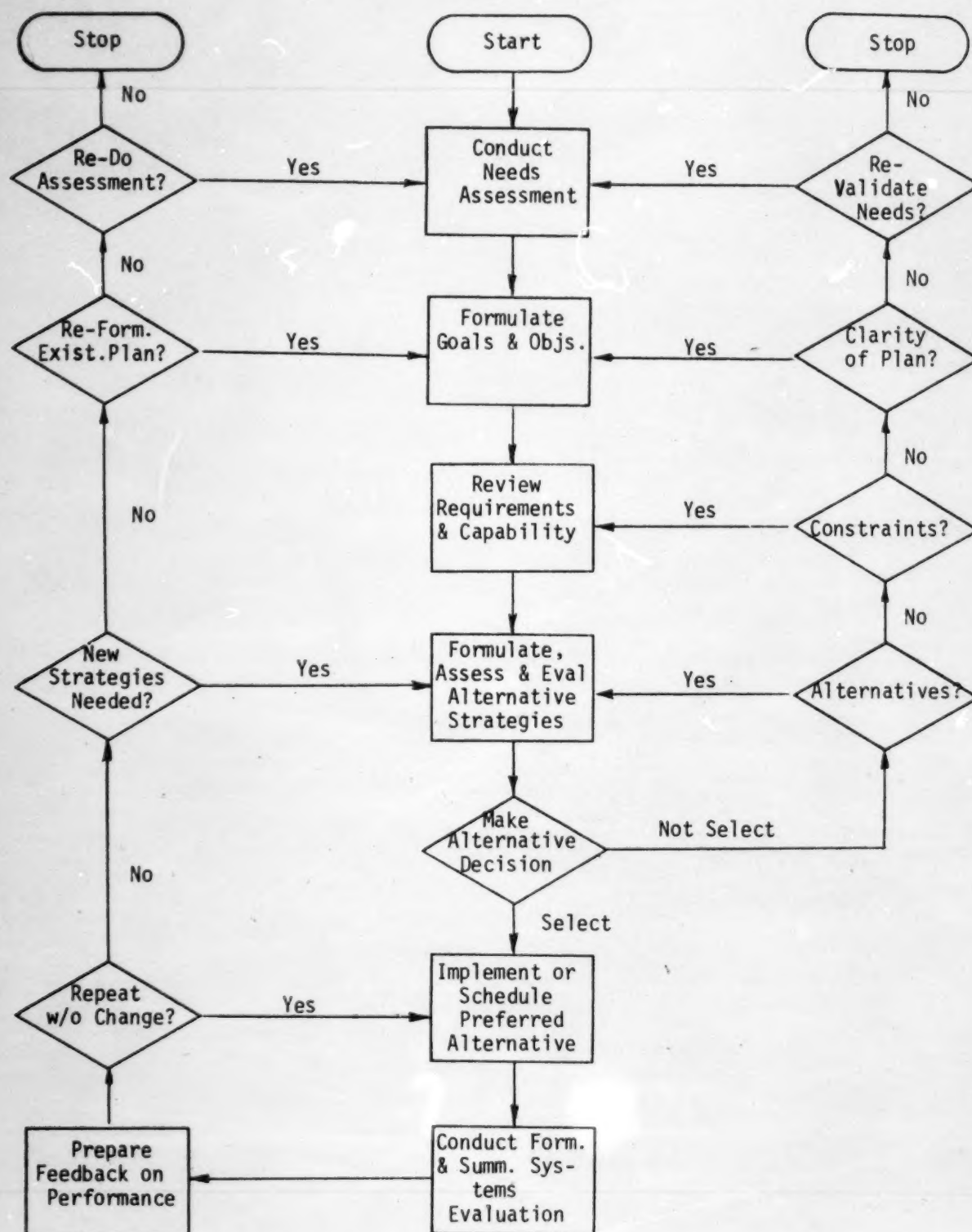


Figure 4. Flow Chart Analysis of The Cyclic Nature of Planning

playscripts, orchestral arrangements, flight plans, toy assembly instructions, data processing applications, federal project development plans, and space vehicle launching plans. The factors which appear to influence or necessitate whether or not a network is generated are:

1. The complexity of the process
2. The iterative or cyclic nature of the process
3. The number of participants involved (communication)
4. The need to standardize a given process
5. The need to coordinate diverse elements

These lead quite naturally to what is proposed as a set of "goodness" criteria against which such efforts or the need for such efforts might be judged. They are:

1. Simplification (understanding complexity)
2. Communication
3. Coordination
4. Codification

Since so many tasks in education could benefit from elaboration and delineation, it is suggested that the technology should be better understood and more systematically applied. Thus, the review of present use was undertaken to discern what elements, relations, and symbols were being used to depict what aspects of the process. It is believed that more systematic and informed use of the information in Table 3 will accomplish the desired result. To this growing body of information it is proposed to add one further dimension - the concept of multi-level process analysis.

Multi-level Process Analysis

All previous examples of networks and most of those found in the literature address single levels of process in a hierarchical sense. There appears to be no reason for limiting process analysis to a single level; in fact, numerous

federal development projects have used PERT methods to achieve enlarged views of sections of previous networks. Furthermore, there seems to be no reason why one or more subsets of symbols representing different approaches could not be combined to address differing variables at different levels. This is the concept of multi-level process analysis which adds a new dimension in terms of depicting contextual and subsystem relations.

An analogy followed by an example may serve to illustrate the concept. Laboratory scientists have need for and frequently use microscopes which are powerful and useful devices. In brief, such highly developed instruments offer a broad range of lenses with which to alter the level of detail under investigation. Such capability facilitates the analysis of contextual relationships at a variety of levels of magnification and provides ready access to increasing levels of specificity which may or may not reveal new arrays of structural elements. The technology of drafting has established and standardized similar procedures. The utility of such expanded use seems clear particularly as the analyst addresses complex organizational processes such as budgeting or scheduling and as there may be need for focusing attention on a subset of the process for an individual or separate entity such as a work group.

Figures 5 and 6 illustrate, though briefly, an example of how a similar "lensing" function might be employed in multi-level process analysis.

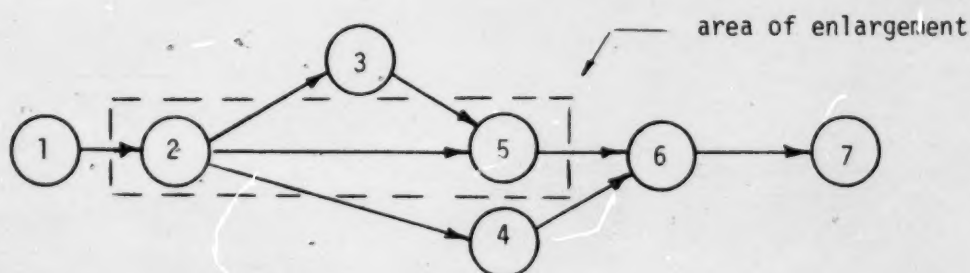


Figure 5. An Example PERT Network

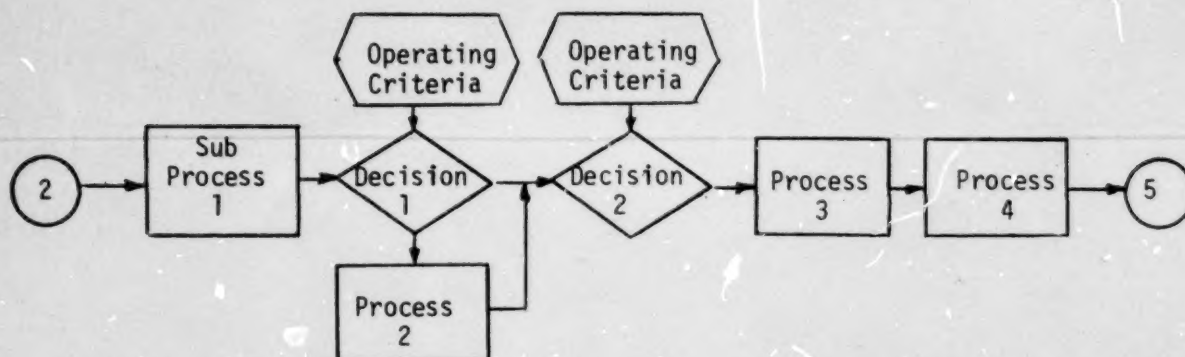


Figure 6. An Enhanced View Of A Network Subsystem

Clearly, the relationship between the two networks establishes the contextual or subsystem interface. In this case, two different symbol sets (or subsets) have been employed to reveal different process elements though flexibility in choice of graphics is obvious. Furthermore, the subnetwork makes possible clear coordination of distributed responsibility without the necessity of lengthy instruction.

Application

Smith (1974) studied the budgeting process in a metropolitan public school district in a midwestern state. At the time the district had 160 separate facilities, 9500 certified staff, 123.5 thousand students, and an annual budget of 188.9 million dollars. The magnitude of the district's annual budget statement belies the complexity of the process which resulted in that product and the nearly intractable problem facing the research analyst.

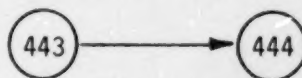
Smith employed document analysis of policy statements, administrative guidelines, fiscal procedural statements, and budgetary products to identify procedural activities, process participants, and intermittent events. On the basis of this data, a preliminary network was developed and interviews of key personnel at all levels of the organization were undertaken. On the basis of this information, a refined, global process network was achieved and validated by re-checking with the few personnel who by virtue of their roles were in possession of a

comprehensive, conceptual picture of the process or at least large component areas.

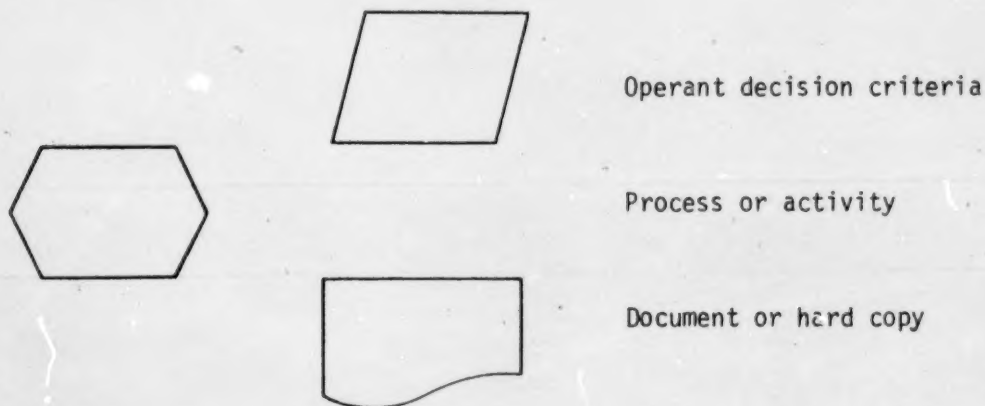
Figure 7 (note the network is continued on two pages) depicts the district budgetary process. The process map represents the first time such a complex educational process had been achieved and was received with considerable interest and appreciation by central administrators of the district.

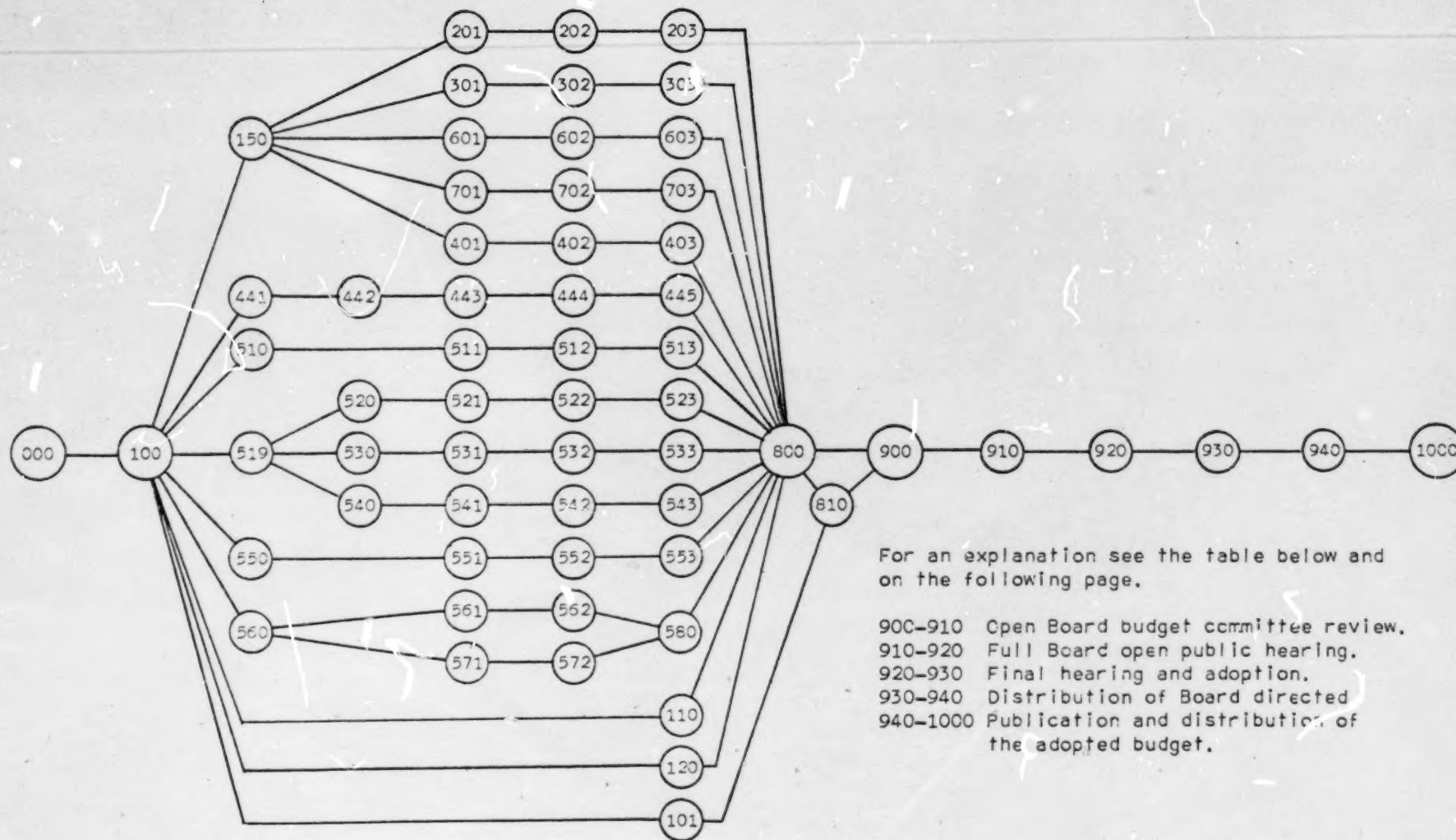
The structural shape of the network reveals a process which begins in singular fashion, distributes itself over numerous, parallel channels and then returns with no observed interaction across paths to a singular chain of activities and events through which all activity ceases. On reflection, such a design is not surprising. In a sense, the map is a communications model stripped of peripheral, incidental interaction.

In the next phase of the study, Smith selected the activity denoted by the symbols



for secondary or micro-level analysis. The sub-process was the function of the Repair Review Board acting upon plant improvement requests. The procedures for investigation were the same as those used in the earlier analysis. Figure 8 depicts the result of the secondary analysis. However, certain symbol interpretations differ from those previously presented and, therefore, the prior usage is given below.





000-100	Review budgetary procedures.	445-800	Re-review plant improvement requests.
100-101	Request preliminary revenue forecast.	510-511	Formulate elementary school requests.
100-110	Prepare fixed charges request.	511-512	Curriculum review of elementary school requests.
100-140	Prepare special and contingent requests.	512-513	Examine elementary school requests.
100-150	Prepare central office budget instructions.	513-800	Review elementary school requests.
100-441	Prepare plant improvement instructions.	519-520	Formulate junior high instructions.
100-510	Prepare elementary school instructions.	519-530	Formulate senior high instructions.
100-519	Prepare secondary school instructions.	519-540	Formulate six-year high instructions.
100-550	Prepare staffing needs request instructions.	520-521	Formulate junior high requests.
100-560	Prepare summer school instructions.	521-522	Curriculum review of junior high requests.
101-810	Prepare preliminary revenue forecast.	522-523	Examine junior high requests.
110-800	Review fixed charges request.	523-800	Review junior high requests.
120-800	Review special and contingent requests.	530-531	Formulate senior high requests.
150-201	Distribute administrative and instructional services instructions.	531-532	Curriculum review of senior high requests.
150-301	Distribute business services instructions.	532-533	Examine senior high requests.
150-401	Distribute repair division instructions.	533-800	Review senior high requests.
150-601	Distribute construction fund instructions.	540-541	Formulate six-year high requests.
150-701	Distribute extension fund instructions.	541-542	Curriculum review of six-year high requests.
201-202	Formulate administrative and instructional services requests.	542-543	Examine six-year high requests.
202-203	Examine administrative and instructional services requests.	543-800	Review six-year high requests.
203-800	Review administrative and instructional services requests.	550-551	Formulate staffing needs requests.
301-302	Formulate business services requests.	551-552	Administrative review of staffing needs requests.
302-303	Examine business services requests.	552-553	Allocate salary estimates for staffing.
303-800	Review business services requests.	553-800	Review salary allocation requests.
401-402	Formulate repair division requests.	560-561	Formulate exceptional education summer school requests.
402-403	Examine repair division requests.	560-571	Formulate regular summer school requests.
403-800	Review repair division requests.	561-562	Administrative review of exceptional education summer school requests.
441-442	Formulate plant improvement requests.	562-580	Examine exceptional education summer school requests.
442-443	Examine plant improvement requests.	571-572	Administrative review of regular summer school requests.
443-444	Review plant improvement requests.	572-580	Examine regular summer school requests.
444-445	Estimate approved plant improvement requests.	580-800	Review summer school requests.
		800-810	Prepare budget revenue requirements.
		800-900	Review proposed budget.
		810-900	Review final revenue forecast.



25

The network is primarily a decision model which depicts operant criteria and activities which follow decision alternatives. The logic of the network is consistent if you consider that written and documented "repair requests" flow through the model. Given the four steps previously noted as describing the act of analysis, the second phase (representation) was completed with the achievement of the network of Figure 8. It is contended that employing the concept of multi-level process analysis significantly advanced the analysis and made an otherwise intractable problem solvable. Further, the secondary network was considerably enhanced because of the understanding of the contextual relations that were achieved in the earlier analysis.

Smith completed the remainder of the study by constructing a computer simulation program which represented the Repair Review Board decision process. Written in Basic Plus and given sufficient input in the form of requests, the program predicted 90% correct decisions when a sample of 80 requests was combined with the human process. This test combined with individual, judgemental review of the decision network constituted the validation and experimentation phases of the analysis.

Summary

This paper introduces the concept and associated technology of multi-level process (MLP) analysis as an important pre-theoretical and practical strategy for analysis. In the course of the discussion, analysis and MLP in particular were differentiated and a variety of examples were examined as a means of achieving common ground for interpretation and estimates of current practice in process modeling. The review provided a basis on which a number of recommendations were advanced to standardize and codify contemporary practice, a number of new questions were raised, and on which a prior study might better be understood. Throughout, the purpose was to propose MLP as a viable strategy for analysis and to reveal by example the associated utility. The summary which follows is an

effort to extract and integrate what are believed to be the important issues addressed in the paper.

The real world abounds with examples of the systematic use and realized utility of in-depth process analysis. Several such examples were identified. In contrast, administration in the public sphere (health agencies, schools, social agencies, etc.) constitutes a notable example where such analytic techniques have been used sparingly. To the extent this trend is beginning to change, there is evidence of non-systematic and non-standardized usage. The increasing evidence of the use of such methods to depict human and organizational processes speaks indirectly to the assigned and realized value and, further, the need to standardize and codify the technology. Recommendations were advanced in this regard.

An examination of contemporary examples of analysis and representation provides a basis for extracting what appear to be the operant advantages associated with process analysis and hence permit an expression of what has been termed "goodness criteria". These were variously expressed as:

1. Potential for enhanced communication
2. Potential for enhanced coordination
3. Potential for enhanced understanding
4. Potential for standardization of process
5. Potential for codification of representation techniques.

Though not explicitly stated, it should have been apparent that MLP analysis has the potential to satisfy each of the above and, in addition, contributes in several other ways. MLP analysis:

1. Adds a new dimension to analytic practice.
2. Adds to understanding -
 - a. in the sense of contextual relations, and
 - b. in the sense of clearly revealing the interface from level to level.
3. Contributes substantially to communication and coordination in that greater detail can be added to network segments by exposing new levels of the process.
4. Enhances the potential for addressing complex problems that appear to be analytically intractable.

The above may not constitute overwhelming evidence, but certainly there is some reason to support the contention that MLP analysis is worthy of further exploration.

Finally, several questions were raised in the course of the discussion that can only be answered by further exploration given the present state of the art.

They are:

1. Is there a universal set of process analysis symbols to be identified, standardized, and codified?
2. Is there any value to be realized as a result of codification?
3. Is process analysis a technique that can and should be transmitted through instruction?
4. What, if any, assumptions are implicit in the use of the technique?
5. What evidence is there to support the notion that process representations are generalizable?
6. Does the Whorfian Hypothesis (there will be as many discrete views of an entity as there are observers) negate generalizability?
7. In what ways is process analysis the same as or different from theory development?
8. Are there, in fact, levels in processes?

Clearly, answers to the foregoing questions will not come easily nor were the answers ever within the scope of this paper. The contention is that multi-level process analysis is a valuable technique with obvious utility in a practical sense and potential value in a theoretical sense given that answers to the above are affirmative as is presently believed.

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